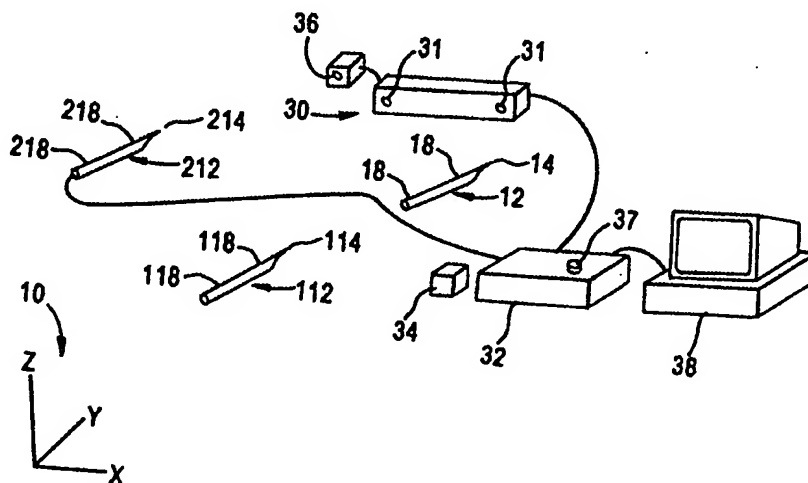




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : G09G 3/02, G08C 21/00, G09G 5/00	A1	(11) International Publication Number: WO 99/52094 (43) International Publication Date: 14 October 1999 (14.10.99)
(21) International Application Number: PCT/US99/07317 (22) International Filing Date: 2 April 1999 (02.04.99) (30) Priority Data: 60/080,587 3 April 1998 (03.04.98) US 60/082,945 24 April 1998 (24.04.98) US (71) Applicant (for all designated States except US): IMAGE GUIDED TECHNOLOGIES, INC. [US/US]; 5710-B Flatiron Parkway, Boulder, CO 80301 (US). (71)(72) Applicants and Inventors: FAUL, Ivan [US/US]; 323 Overlook Lane, Boulder, CO 80302 (US). SCHULZ, Waldean, A. [US/US]; 440 Japponica Way, Boulder, CO 80304 (US). SKELTON, Brett, R. [US/US]; 145 Jackson Drive, Boulder, CO 80027 (US). PASQUINI, RONALD, M. [US/US]; 3050 Corona Tr. #304, Boulder, CO (US). (74) Agent: BERNER, Kenneth; Lowe Hauptman Gopstein Gilman & Berner, LLP, Suite 310, 1700 Diagonal Road, Alexandria, VA 22314-2848 (US).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i>

(54) Title: WIRELESS OPTICAL INSTRUMENT FOR POSITION MEASUREMENT AND METHOD OF USE THEREFOR

**(57) Abstract**

Disclosed is a wireless instrument tracking system. The wireless instrument tracking system is used for determining the location of at least one point relative to the instrument in a three-dimensional space relative to a three-dimensional coordinate tracking system. Advantageously, a first wireless instrument can be placed into the optical field with the wireless instrument including a wireless receiver and at least one optical position indicator. The optical position indicator is typically light emitting diodes (18) and communicates with corresponding measurement sensors (30) across a wireless optical link. The wireless optical link is time multiplexed with repetitive time frames divided into time slots. Each LED (18) emits an infrared signal or flashes in a respective time slot of a time frame. The measurement sensors (30) are preferably CCD cameras. The LEDs (18) are synchronized with the cameras and once synchronized each LED (18) flashes in a different time slot in synchronization with the camera frame rate.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LJ	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

WIRELESS OPTICAL INSTRUMENT FOR POSITION MEASUREMENT
AND METHOD OF USE THEREFOR

This application claims priority of U.S. Provisional Patent Application Serial No. 60/080,587 filed April 3, 1998, entitled "OPTICALLY TRACKED WIRELESS INSTRUMENTATION" and U.S. Provisional Patent Application Serial No. 60/082,945 filed April 24, 1998, entitled "WIRELESS MEASUREMENT INSTRUMENT AND
5 SYSTEM FOR POSITION MEASUREMENT AND METHOD OF USE THEREFOR", the disclosures of which are incorporated by reference herein in their entirety.

Field of the Invention

The present invention relates to optical instruments for position measurement, and more particularly, is directed to wireless optical instruments for position measurement.

10

Background of the Invention

Systems using wired optical instruments for position measurement are known. One such system is an a FlashPoint 5000 system (FP5000) which is commercially available from Image Guided Technologies, Boulder, Colorado. The FP5000 system
15 includes multiple instruments, a camera system and a control unit. The control unit sends synchronization signals to the instruments via instrument cables and a break out box (if equipped). A measurement camera system includes two or more camera heads. By receiving the synchronization signals, infrared light emitting diodes (LEDs) on the instruments flash in synchronization with the camera frame rate (individually or in
20 groups, time multiplexed). Each of the cameras images light emitted by the LEDs, and the measurement system uses the images to provide data. The data are converted to

measurement angles by the measurement system and the measurement angles are sent to the control unit. The control unit converts the measurement angles to x, y and z coordinates of the LEDs. The control unit can convert the locations of the LEDs to an x, y, z position of the instrument and an orientation of the instrument. The instrument can, in addition, transmit instrument data to the control unit via the instrument cable. This information includes: button states, calibration data, probe ID, type and serial number, probe tip length, temperature and pressure.

Although wired optical instruments are satisfactory in the majority of applications, the requirement for a wire to connect the instrument to the control unit can be cumbersome. Thus, there is a need in the art for a system using a wireless optical instrument for position measurement.

Summary of the Invention

It is, therefore, an object of the present invention to provide a system using a wireless instrument for position measurement.

Another object of the present invention is to provide an apparatus and method of use thereof in which a wireless optical instrument is synchronized with a controller.

It is yet a further objective of the present invention to provide a method of anticipating when an optical indicator should emit light.

Yet another object of the present invention is to provide a method where additional wireless instruments can be introduced into an optical field and assigned a particular multiplexed time slot.

Yet another object of the present invention is to provide a method of time multiplexing multiple optical instruments in an optical field.

These and other objects of the present invention are achieved by a wireless instrument tracking system. The wireless instrument tracking system is used for determining the location of at least one point in a three dimensional space relative to a three dimensional instrument tracking system. Advantageously, a first wireless instrument can be placed into the optical field with the wireless instrument including a wireless receiver and at least two optical position indicators. Two optical position indicators are required to compute orientation, but if only the location of the instrument is

needed, one optical position indicator would suffice. The optical position indicators are typically light emitting diodes (LEDs) and communicate with corresponding position measurement sensors across a wireless optical link. The wireless optical link is time multiplexed with repetitive time frames divided into time slots. Each LED emits an
5 infrared signal or flashes in a respective time slot of a time frame. The measurement sensors are preferably charge coupled device (CCD) cameras. The LEDs are synchronized with the cameras and once synchronized each LED flashes in a different time slot in synchronization with the camera frame rate (individually or in groups). Additional wireless instruments can be placed into the optical field. In a non-auto
10 configuring system, each instrument is pre-assigned to a particular time slot. Because each instrument is pre-assigned a time slot, a carrier signal can be used to trigger the emitters. Advantageously, in an automatically configuring system, additional wireless instruments are not assigned a particular time slot but instead use one time slot as a search channel. The additional instrument is called an unconfigured instrument. The
15 unconfigured instrument or instruments (for example, at startup) are dynamically assigned to a particular time slot by the controller. Collisions are arbitrated using known arbitration schemes such as an ALOHA scheme.

The foregoing objects are also achieved by a wireless instrument tracking system for determining the location of at least one point in three dimensional space relative to a
20 three dimensional instrument tracking system. The instrument tracking system includes a first wireless instrument, including a receiver and at least one optical position indicator. At least two corresponding sensors sense optical signals emitted from the at least two optical position indicators across an optical link. A controller includes a transmitter which can transmit signals to the receiver across a wireless link and means are provided
25 for determining the location of the one optical position indicator relative to the coordinate system.

The foregoing objects are also achieved by a method of determining a location of at least one point in an optical field, the optical field being a three dimensional space relative to a three dimensional coordinate system. A first wireless instrument is placed
30 into the optical field. The first wireless instrument includes a receiver and at least one optical position indicator. The first wireless instrument is synchronized with a controller.

The controller includes a transmitter that can transmit signals to the receiver across a wireless link. The optical position indicator may also transmit data and synchronization to receivers associated with the controller, by modulating the output from the position indicators.

5 The system transmits synchronization signals to the instruments via the wireless link. Upon receiving the synchronization signals, the infrared LEDs on the instruments flash in synchronization with the camera frame rate. The measurement camera array images the LEDs, converts the data to measurement angles and sends it to the control unit. The control unit converts the measurement angles to x, y and z coordinates of the
10 LEDs, and eventually, if required, to an x, y, z position and orientation of a rigid body having multiple LEDs are attached to. The instruments can, in addition, transmit instrument data to the control unit via the wireless link. The data can include button states, calibration data, probe ID, type and serial number, probe tip length, temperature and pressure.

15 Still other objects and advantages of the present invention will become readily apparent to those of ordinary skill in the art from the following detailed description, wherein the preferred embodiments of the invention are shown and described, simply by way of illustration of the best mode contemplated of carrying out the invention. As will be realized, the invention is capable of other and different embodiments, and its several
20 details are capable of modifications in various obvious respects, all without departing from the invention. Accordingly, the drawings are to be regarded as illustrative in nature, and not as restrictive.

Brief Description of the Drawings

25 The present invention is illustrated by way of example, and not by limitation, in the figures of the accompanying drawings, wherein elements having the same reference numeral designations represent like elements throughout and wherein:

Figure 1 is a perspective schematic view of the wireless system of the present invention;

30 Figure 2 is a perspective view of a probe, light source and optical indicators;

Figure 3 is a schematic diagram of a converter circuit; and

Figure 4 is an illustration of time slots within a time frame.

Best Mode Contemplated for Carrying Out the Invention

A method and apparatus of using and configuring a wireless instrument in an optical field in accordance with the present invention are described. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It should be apparent, however, that the invention may be practiced using other, different specific details. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the present invention.

In Figure 1, a rectangular three dimensional coordinate system generally indicated at 10 is illustrated. An optical tracking system for measuring the location and orientation of an optical probe is also depicted in Figure 1. As used herein, position means the location or orientation (as in an upright or inverted position). Thus, position includes a location and orientation. The system includes a first wireless optical probe, generally indicated at 12, that has a tip 14. The system also includes a second wireless optical probe, generally indicated at 112, that has a tip 114. A wired probe is generally indicated at 212 that has a tip 214. The system can accommodate any number of objects to be simultaneously tracked, although tracking of up to about eight objects is preferred. Each of the probes 12, 112, 212 is considered an object to be tracked. On the object to be tracked, depicted as the probe 12 are located energy emitting elements 18 such as LEDs. The energy emitters include optical position indicators such as LEDs. Alternatively, passive markers such as reflective, shiny balls can be substituted for the energy emitters 18. The energy emitters 18 are preferably electromagnetic ray emitters. Object 12 need not be a probe as depicted, but also can be a reference frame, removable pod, a single LED or any other object to be tracked in the three dimensional coordinate system. The instruments can be identical or different. An exemplary reference frame is a Dynamic Reference Frame™ (DRF), commercially available from Image Guided Technologies, Boulder, Colorado.

In Figure 2, two light emitting diodes 20 are depicted which serve as generators of electromagnetic radiation (the light sources). Although the invention contemplates any number of light sources, only two light sources per probe 12, 112, 212 are depicted. Each energy emitter 20 can disperse the light into a wide radiation pattern 28. Other and different instruments can be used as described in co-pending patent application Serial No. 08/870,296 filed June 6, 1997, entitled "Optical Fiber Probe for Position Measurement" which is assigned to the instant assignee and which is incorporated into the present specification in its entirety.

A sensor assembly 30 includes at least two charge coupled device cameras 31 as depicted in Figure 1. Exemplary electromagnetic rays 28 radiate outward from each of the emitter elements, a few of which are seen by each of the CCD cameras 31. A controller 32 controls the sensor assembly 30 and the light sources. A transceiver 34 is coupled to controller 32 as depicted in Figure 1. A photo diode 36 is coupled to the sensor assembly 30 and is in communication with controller 32. Optionally, a contact or connector 37 is mounted to controller 32 and is used to transfer information to a mating connector or contact 39 mounted on one end of probe 14 as depicted in Figure 2. An otherwise conventional computer 38 receives input of the data from controller 32. From these data, computer 38 can calculate the x, y, z coordinates of the location of each element, 18 or 26, etc., which appears as a substantial point source of light. From the thus determined coordinates of each emitter, and the known geometry of the probe, the computer 38 can also compute the location and orientation of the probe and therefore can determine the location of any point on the probe, such as the probe tip. Computer 38 also determines the unit 3-D vector describing the longitudinal direction of the probe (which is one aspect of the orientation of the probe). These calculations can also be performed by the controller 32. If more than two non-collinear electromagnetic energy ray emitters are disposed on the probe, a transverse 3-D vector can also be computed to describe the rotational orientation of the probe or its yaw-pitch-and-roll angles.

The light from each LED can be modulated and the modulated light can be received by the photo diode 36. Because the signal is modulated, additional information can be included and sent to the controller 32. Because the cameras 31 integrate the light

signal, the cameras do not sense that the light signal is being modulated. The photocells 36 or photodiodes are not used to sense the location of the instruments 12, 112.

Optional connector 37 and connector 39 can be used in addition or alternatively to transfer information from the probe to the control unit or from the controller 32 to the probe 12, 112. A momentary contact at the beginning of the procedure between probe 12, 112 and the controller 32 can be used for the transmission of "smart" information to the controller 32 and to "register" the probe's existence as an active instrument to the controller 32. The transfer of such "smart" information to the controller 32 includes a transfer of information such as instrument calibration, serial number, instrument ID, and the like. The storage and transmission of such information across wires is already covered by U.S. Patent No. 5,617,857, entitled "Imaging System Having Inner Active Medical Instruments and Method" and is assigned to the instant assignee and is hereby incorporated into the present specification in its entirety.

Mounted on the probe 12 is a wireless transceiver 40, as depicted in Figure 2. Transceivers 34 and 40 are in wireless communication with each other over a wireless link.

The probe 12 includes a memory module 42 in which is stored the smart information. The memory module 42 may be integrally formed with the probe 12 or included as a separate attachment. The EPROM chip may be preprogrammed with a variety of initialization information including the serial number of the instrument, the instrument type or part number, the number of buttons on the instrument, the number of energy-emitting elements on the instrument, the local x, y, z coordinates of the tip or other reference location on the instrument, the local unit direction vectors of the "longitudinal direction" of the instrument, the local unit direction vectors of the "transverse direction" of the instrument, the local x, y, z coordinates for each of the energy-emitting elements, customer specific information and the like.

In Figure 3, a circuit is depicted for rejecting interfering light signals when the wireless link uses light energy in the IR range. The circuit includes a circuit converter 50 which converts an incoming light signal received by a sensor 40 into an electrical signal. The converted electrical signal includes both a data carrier as well as an unwanted ambient interference signal. A filter circuit 52 is coupled to the converter circuit 50. The

filter circuit 52 separates the interference signal from the combined signal relying on the fact that the interference signal is of a much lower frequency. An interference signal and data carrier signal are output from filter circuit 52 separately presented to a high common mode rejection amplifier 54 which provides more amplification to the data carrier signal than to the interference signal. A discrimination circuit 56 is coupled to the amplifier 54 and can discriminate between the data carrier frequency that is known and any interference signal that may remain in the output of the data carrier signal.

Additional buttons can optionally be provided on the probe 12. This would provide for "wireless" buttons, either on the instrument or provided separately. A separate button would require an additional emitter 18 for transmission of its state.

Optical filters 57 can be used to block unwanted ambient light energy. These filters can be short pass or long pass or a combination of both to provide a band pass function.

Advantageously, the present invention is able to operate under high ambient lighting conditions such as operating room (OR) lights (medical applications) or sunlight (industrial applications). This is accomplished by a combination of filtering, common mode rejection and frequency discrimination as depicted in Figure 3.

There are two wireless data communication links used in the present invention. The first data link is a wireless data link between transmitter 34 and receiver 40 mounted on probe 14. This data communication link can be infrared, radio frequency or ultrasound. The second wireless communication link is between emitters 18 or 26 and receiver 36.

Both of the wireless links are divided into time frames, that is, each is time multiplexed. For example, as depicted in Figure 4, a time frame could be divided into nine time slots, the duration of which depends on the number of markers or emitters on the instrument. In this configuration, eight wireless instruments can be placed into the optical field with each having a time slot associated therewith. Each instrument would be assigned the same time slot for the wireless link as well as for the optical link with a possible slight time off set between the time slots. The ninth time slot will serve as a search channel for adding unconfigured instruments to the system. The optical time slot might be slightly delayed behind the wireless time slot. In accordance with the present

invention, a wireless instrument needs to be synchronized to the controller 32 so that the optical indicators 18 or 26 will emit light or flash in synchronization with the camera frame rate. One way of maintaining synchronization between the wireless probe and controller 32 is to use a high accuracy, low drift clock in both the control unit and wireless instrument 12 which would require only initial or infrequent synchronization between controller 32 and probe 12.

The system could also derive synchronization from a common external source, such as the 60 or 50 hertz that is being radiated by nearby electrical apparatus. The system could also derive synchronization from time signals being transmitted by satellites, other wireless carriers or infrared strobes.

One advantage of using a low drift clock is that a problem occurs if an instrument loses line-of-sight contact with the controlling synchronization signal and that the LED timing cannot be extracted. Utilizing low drift, high accuracy clocks in both probe 12 and controller 32 allows both to run without any signaling therebetween for a significant time period after initial synchronization. The length of the time period is determined by the stability of the clocks. The clock stability can be chosen to maintain synchronization and to only bridge temporary communication drop outs, or it can be chosen to ensure synchronization during the entire use of the wireless instrument 12. In the latter case, the instrument 12 that was synchronized with the controller 32 at the beginning of a measurement session would not have to be resynchronized during the same session.

Another method which would reduce system complexity by not requiring data communication to the wireless instruments, would be achieved by having the wireless instrument 12 fire its indicators or LEDs 18 asynchronously of their own accord. The controller 32 would learn the asynchronous firing pattern and would synchronize its measurement functions by using the timing information derived from the wireless instrument 12.

Yet another method of facilitating synchronization of the controller 32 and all instruments 12, 112 would be to use an external clock that would establish reception of a common clock signal by all instruments 12, 112. This clock signal can be transmitted by a central clock, or can be received from new satellites or already existing satellites (such as GPS satellites) or can be received from radio frequency time beacons.

Unlike a conventional wired system in which the controller 32 can discern the addition of an additional probe 12, in a wireless system the controller 32 must be able to recognize that an additional instrument 12 has entered the optical field. Two systems are possible: a first and simpler system termed a non-auto configure system, and a second system termed an auto configuring system. The advantage of the auto configuring system is that instruments do not have to be pre-assigned to a particular time slot.

In a non-auto configuring system, each instrument 12, 112, 212 would be assigned or dedicated to a particular time slot. The position indicators 18 of each instrument can be synchronized in a non-auto configuring system in one of two ways. In the first way, the transmission of the carrier only indicates the time slots for emitters 18 to emit energy such as LED flashes. The presence of a carrier will signal to the instrument 12, 112, that an LED should be fired. In the absence of the carrier, no LEDs will be fired. The carrier pulses are counted by each of the wireless instruments 12, 112, and the next LED is fired after each consecutive pulse is counted. Each instrument is assigned a number of LEDs in the pulse sequence. For instance, 20 pulses are transmitted to five probes, each containing four LEDs. Instrument 1 will fire its LEDs during the first four carrier pulses (pulses 1 through 4), instrument 2 during the second four pulses (pulses 5 through 8) until instrument 5 fires its LEDs during the last four pulses (pulses 17 through 20). At the end of the cycle, instrument 1 will again pick out pulses 1 through 4. This method of time multiplexing will distinguish one instrument 12, 112 from another instrument 12, 112. To synchronize the instruments with the start of the carrier pulse stream, a "quiet" time during which no pulses are transmitted precedes the pulse stream in order to synchronize the instruments.

A slightly more complex but more intelligent method of controlling instrument energy emitters 18 or LEDs is the transmission of an instrument identification code (ID) as an "address" indicating which instrument 12 should fire its LEDs. The transmission of synchronization pulses to the instruments 12, 112 would be similar to the previously described method, except that the pulse does not include only a carrier, but also includes a modulated signal. The modulated signal contains data representative of an LED identifier. The LED identifier is received by all instruments and if it matches the ID of an LED on a specific instrument, that instrument will fire that particular LED. The LED

identifier can be transmitted multiple times during a pulse to improve immunity against noise and false reception. In the implementation of the system for use under noisy conditions, the number of ID transmissions per pulse is unique to the instrument and each ID is counted. The instrument 12, 112 can thus anticipate the end of the pulse transmission and if a drop out occurs, it will self-time the pulse duration and turn the LED off at the correct time.

The auto configuring network allows instruments to be introduced into the optical field and removed from the optical field. Unconfigured instruments will be automatically recognized when first introduced into the optical field, uncommitted time slots will be arbitrated, and the instrument will be added to the active list of instruments being tracked. Collisions due to the simultaneous introduction of multiple increments will be resolved.

The operation of the auto configuration method is as follows. During operation with multiple instruments visible in the field, each instrument operates in a time slot assigned to that instrument after first being introduced into the optical field. Each optical instrument, however, is not pre-assigned to a particular time slot. Thus, more than eight instruments can be used within the system although only eight can be tracked at any particular time. Within an allotted time slot, the instrument sequentially fires all the LEDs it contains. When a new instrument is introduced into the optical field, it does not have a time slot assigned and cannot fire its LEDs without potentially interfering with existing instruments 12, 112 already in the optical field. The new instrument is referred to as an unconfigured instrument and the existing active instruments are referred to as configured instruments.

A method is established where all unconfigured instruments are assigned a shared time slot (search channel) that is used whenever the unconfigured instrument is brought into the field of view for the first time. An unconfigured instrument communicates with the controller 32 in this time slot until it is assigned to a dedicated time slot. This instrument then becomes a configured instrument. If multiple instruments are brought into the field of view simultaneously, data collisions can occur as more than one instrument attempts to communicate with the controller 32 at the same time. A data arbitration scheme is implemented to resolve such conflicts. This will happen, for example, if multiple instruments are in the field of view when the system first starts

operation. To facilitate the unique identification of each instrument and the LEDs it contains, an LED identification code will be transmitted by the controller 32. One method of resolving such collisions is known as the ALOHA method which is well known in the art.

5 For either the auto configuring or the non-auto configuring systems, where the wireless link is bit rate limited (such as RF and ultrasound), a protocol that enables the instrument 12, 112 to "anticipate" the next LED to flash by providing advance information will be possible. A predictive algorithm operates as follows: a control circuit in the controller 32 records the sequence of LEDs that are being flashed. The sequence is
10 analyzed to determine the repetitive pattern's length and the specific sequence of LEDs in the pattern. By having learned the LEDs sequence, the control circuit of the controller 32 knows ahead of time when an LED will be asked to turn on during the ongoing cycling through the LED sequence. This "prediction" will be transmitted to the wireless transducer at least one LED time slot ahead of the actual turning on of each LED. This
15 will allow the complete transmission of which LED is required to turn on before it is necessary to actually turn it on, facilitating the timely turn-on of the LED. This is particularly useful for ultrasound which also involves additional propagation delays, which in fact would force the controller 32 to estimate the extra propagation time based on the last known location of the instrument 12, 112.

20 It should now be apparent that a system for using a wireless instrument has been described in which the wireless instrument or instruments can be synchronized to a controller. Advantageously, up to eight wireless instruments can be introduced into the field of view at any one time. In a non-auto configuring network, the system is limited to using eight instruments which are pre-assigned to particular time slots. In an auto
25 configuring network, more than eight instruments can be used of which only eight instruments being used at any one time.

It will be readily seen by one of ordinary skill in the art that the present invention fulfills all of the objects set forth above. After reading the foregoing specification, one of ordinary skill will be able to affect various changes, substitutions of equivalents and
30 various other aspects of the invention as broadly disclosed herein. It is therefore intended

that the protection granted hereon be limited only by the definition contained in the appended claims and equivalents thereof.

What is Claimed Is:

1. A wireless instrument tracking system for determining the location of at least one point in three dimensional space relative to a three dimensional coordinate tracking system, comprising:
 - 5 a first wireless instrument including a receiver and at least one optical position indicator;
 - at least two corresponding sensors for sensing optical signals emitted from said at least one optical position indicator across an optical link;
 - a controller including a transmitter which can transmit signals to said receiver across a wireless link and means for determining the location of said at least one optical
10 position indicator relative to the coordinate system.
2. The system of claim 1, wherein said receiver and said transmitter communicate over one or more of an RF link, an infrared link and an ultrasound link and wherein the receiver and transmitter are each a transceiver and the link is a two-way transmission-reception link.
3. The system of claim 1; wherein said sensors are CCD cameras.
4. The system of claim 1, wherein said optical position indicators are reflective markers.
5. The system of claim 1, wherein said optical position indicators emit electromagnetic radiation.
6. The system of claim 1, further comprising modulation sensors for sensing a modulated optical signal emitted from each of said two optical position indicators.
7. The system of claim 1, further comprising at least one of a short pass filter and a long pass filter positioned in an optical path between said sensor said transmitter on the controller.

8. The system of claim 1, further comprising:

a converter for converting the optical signal into an electrical signal, the electrical signal including a combined signal of a data carrier and an interference signal; and

a filter circuit for separating the interference signal from the combined signal and
5 a high common mode rejection amplifier for amplifying the separated data carrier signal more than the interference signal.

9. The system of claim 1, wherein said wireless instrument further comprises a memory.

10. The system of claim 9, further comprising means for transferring information from said memory to said controller.

11. The system of claim 1, wherein the optical link is divided into repetitive time frames, and each time frame is divided into time slots.

12. The system of claim 1, further comprising at least one additional wireless instrument including a receiver and at least two optical position indicators.

13. The system of claim 12, wherein the optical link is divided into repetitive time frames and each time frame is divided into time slots and wherein said first instrument is assigned a particular time slot in each time frame and said second instrument is assigned a particular different time slot in each time frame.

14. The system of claim 1, further comprising a low drift clock in each of said first wireless instrument and said controller.

15. The system of claim 11, wherein the duration of each time frame is dependent on the number of optical position indicators mounted on each instrument.

16. The system of claim 1, wherein said first wireless instrument and said controller each include means for receiving a clock signal from an external clock for synchronization.

17. The system of claim 5, wherein the optical indicators are light emitting diodes.

18. The system of claim 1, further comprising a wired instrument including at least two optical position indicators, the wired instrument connected to said controller by a wired path.

19. The system of claim 1, wherein the instrument is one of a probe, a reference frame, a removable pod or a single LED.

20. A method of determining the location of at least one point in an optical field, the optical field being in three dimensional space relative to a three dimensional coordinate system, comprising:

- placing a first wireless instrument into the optical field, the first wireless instrument including a receiver and at least one optical position indicator;
- synchronizing the first wireless instrument with a controller, the controller including a transmitter which can transmit signals to the receiver across a wireless link;
- the optical position indicator transmitting data in synchronization with sensors associated with the controller.

21. The method of claim 20, wherein optical position indicators flash at a rate and the sensors are CCD cameras having a frame rate in synchronization with the flash rate of the optical position sensors.

22. The method of claim 20, comprising determining the location of the at least one optical position indicators relative to the coordinate system.

23. The method of claim 20, comprising modulating the optical signal emitted by each of said optical position indicators and receiving the optical signal by the controller.

~~24. The method of claim 20, comprising transferring data to the controller from the first wireless instrument, the data including at least one of instrument calibration data, instrument serial number, instrument identification.~~

~~25. The method of claim 20, comprising placing a second instrument into the optical field, the second instrument in communication with the controller and having at least two optical position indicators.~~

26. The method of claim 25, wherein the second instrument is wireless and includes a receiver.

~~27. The method of claim 25, wherein the second instrument is wired and is connected to the controller by a wired path.~~

~~28. The method of claim 20, comprising anticipating when each of the two optical position indicators transmits data.~~

29. The method of claim 28, comprising recording a sequence of repetitive transmissions of synchronization signals from the controller and analyzing the sequence to determine the length and pattern of data transmission.

30. The method of claim 28, comprising transmitting a control signal from the controller to the first wireless instrument before the next data transmission of each of the optical position sensors.

31. The method of claim 20, comprising dividing the optical link into repetitive time slots and assigning each of the instruments a particular time slot.

32. The method of claim 20, wherein each optical position indicator emits light during the time slot assigned to the instrument on which the optical position indicator resides.

33. The method of claim 20, wherein one of the repetitive time slots is used as a shared time slot arbitrate an assignment of non-assigned instrument being introduced into the optical field.

34. The method of claim 33, wherein an ALOHA scheme is used to arbitrate collisions between multiple instruments being introduced simultaneously into the optical field.

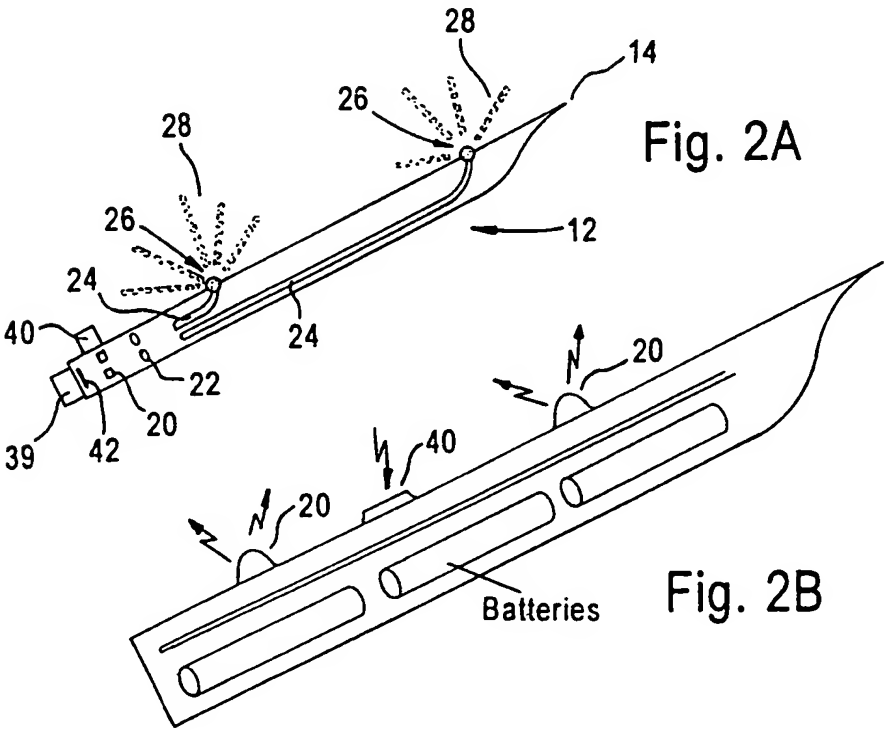
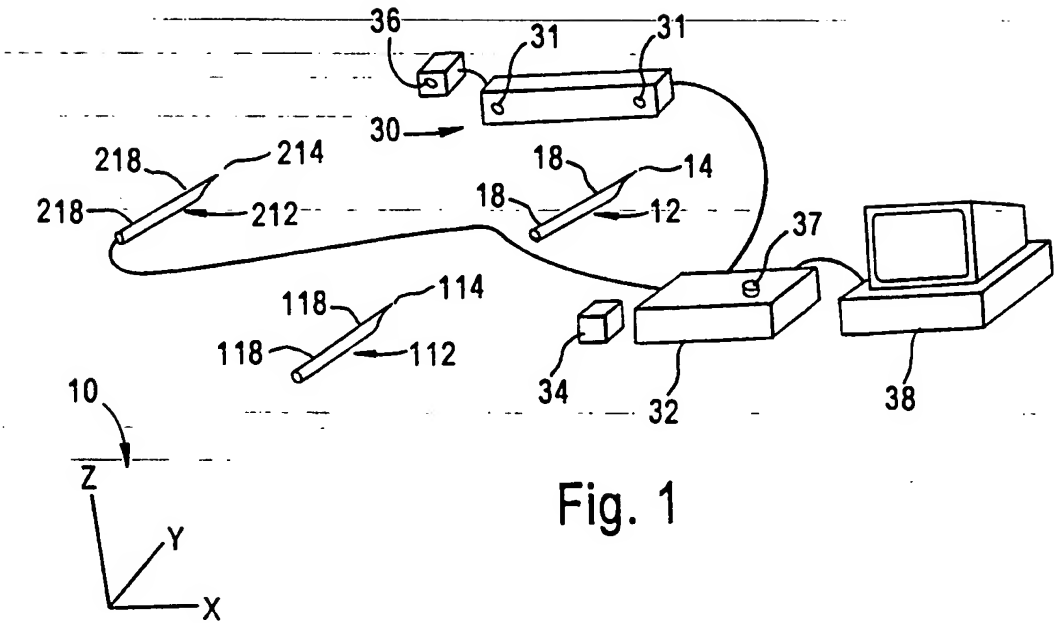
35. The method of claim 20, wherein said synchronization step is maintained by using low drift clocks in the first wireless instrument and in the controller.

36. The method of claim 20, wherein the synchronization step is performed by having a single wireless instrument asynchronously emit an optical signal and the controller learns the asynchronous pattern.

37. The method of claim 20, wherein said synchronization step is performed by receiving a common clock signal at the first wireless instrument and at the controller.

38. The method of claim 25, comprising transmitting a pulsed signal from the controller and counting the number of pulses at each of the instruments and emitting light from a respective optical position indicator based on the counted pulsed signal, and comprising designating when a cycle of pulses begins.

39. The method of claim 25, comprising transmitting a signal including information representative of an identifier for each optical position indicator, each optical position indicator emitting light when the signal includes the identifier.



2/2

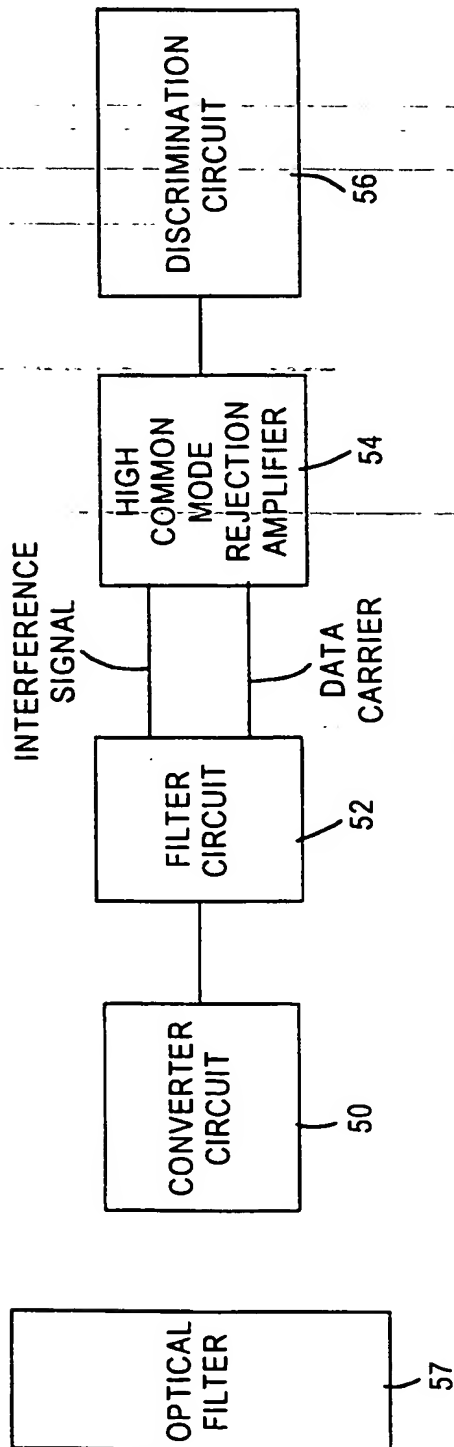


Fig. 3

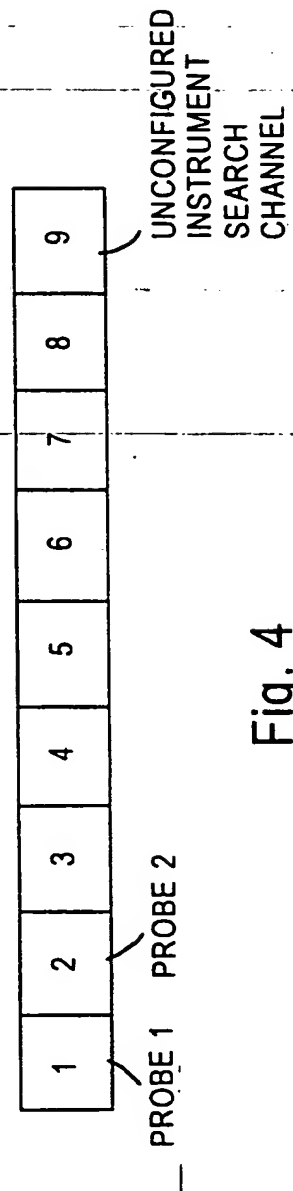


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/07317

A. CLASSIFICATION OF SUBJECT MATTER IPC(6) :G09G 3/02; G08C 21/00; G09G 5/00 US CL :Please See Extra Sheet. According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) U.S. : 356/375; 345/175, 179, 180; 364/559, 410, 449, 516, 517, 453, 578 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched NONE Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) U.S. PTO APS		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y,P	US 5,831,601 A (VOGELEY et al.) 03 November 1998 (03/11/98) see entire document.	1-39
Y,P	US 5,819,206 A (HORTON et al.) 06 October 1998 (06/10/98) see entire document.	1-39
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
A document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	
E earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*A* document member of the same patent family	
O document referring to an oral disclosure, use, exhibition or other means		
P document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search	Date of mailing of the international search report	
19 MAY 1999	27 MAY 1999	
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer M. P. STAFIRA Telephone No. (703) 308-9120	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/07317

A. CLASSIFICATION OF SUBJECT MATTER:

US CL :

356/375; 345/175, 179, 180; 364/559, 410, 449, 516, 517, 453, 578